1.1 The Long Beginning

Figure C1.1: The Slave Granite, home to migrating pelicans and deadly rapids, is among Alberta's oldest exposed rock.

For the last 2500 years, people of the Dene Th'a First Nation have followed the current of the Slave River north as they travel to their hunting grounds. Along the way they've always had to portage—carry their canoes—around a peculiar belt of reddish-coloured granite rock that cut across the river, creating four sections of deadly rapids. Later in Alberta's history, the portage trails established by the Dene Th'a were used by fur traders who ominously named the last of the four rapids "The Rapids of the Drowned."

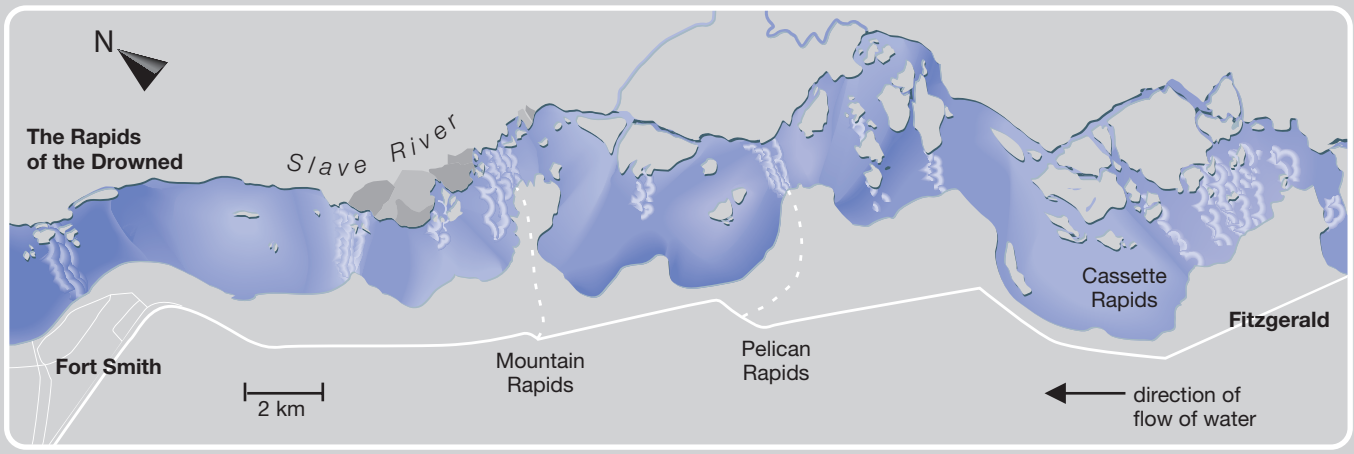


Figure C1.2: People of the Dene Th'a First Nation traditionally had to portage four sections of deadly rapids on the Slave River.

The Precambrian Shield

The strange red belt of granite rock is now called the Slave Granite. At two billion years old, it is among Alberta's oldest rocks. The Slave Granite is part of the Precambrian Shield, often called the Canadian Shield, which was formed in the **Precambrian Era**. The Precambrian Shield is what's left of the original North American continent, which formed four billion years ago. It makes up more than half of Canada's land mass, including most of Ontario and Quebec. In most places in Alberta, you would have to dig several thousand metres below the surface to reach this basement rock. When a rock layer that is normally underground is exposed, like the Slave Granite, it is called an **outcrop**. Other examples of outcrops, such as those noted in Figure C1.4, are mountain rock faces, canyon walls, river valley cliffs, and coastal cliffs.

Precambrian Era: the first major section of geological time, lasting from the origin of Earth 4.5 billion years ago up to 590 million years ago

outcrop: a part of a rock formation that appears above the surface of the surrounding land

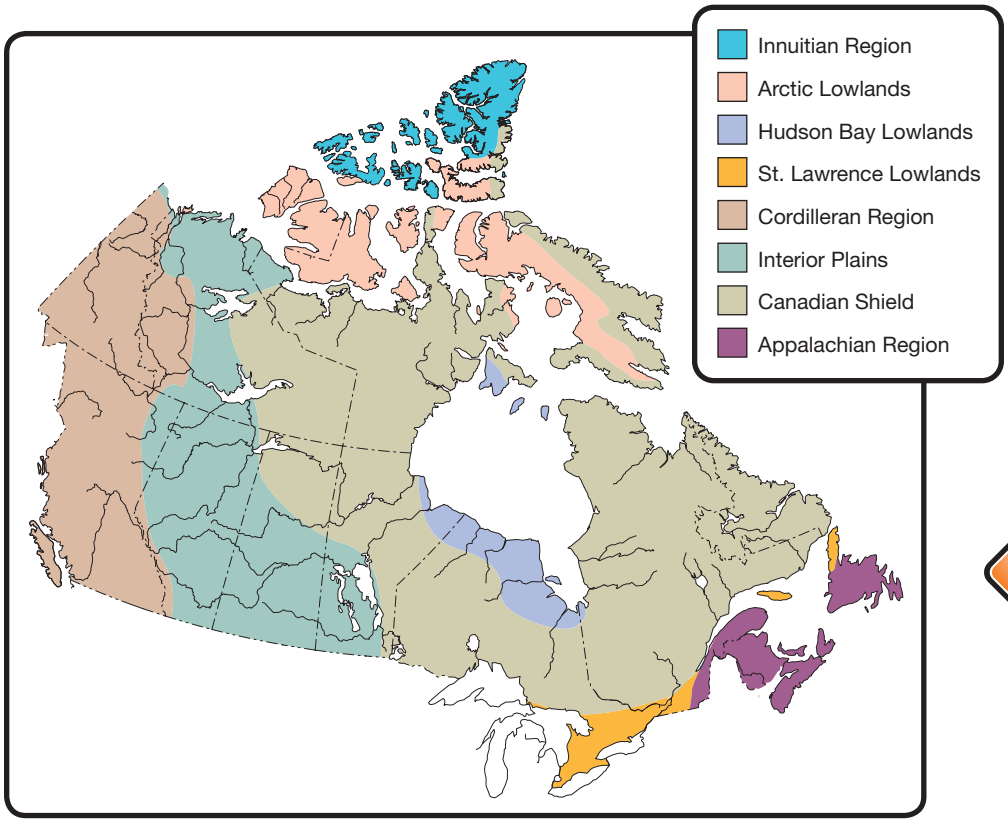


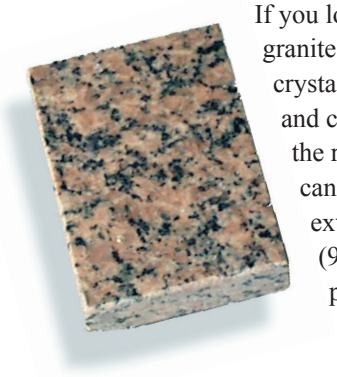
Figure C1.3: The Canadian Shield is one of the eight main physiographic regions of Canada.

Add the following details to your time line for this chapter:

- 4 billion years ago: North American continent formed
- 2 billion years old: age of Alberta's oldest rocks

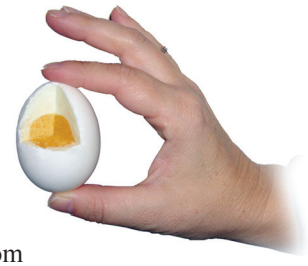
Figure C1.4: Outcrop examples reveal a remarkable diversity.

Earth Is Like an Egg



If you look closely at a sample of granite, you can see large mineral crystals of various shapes, sizes, and colours peppered throughout the rock. Some of these minerals can be formed only under extremely high temperatures (900°C to 1000°C) and pressures.

If the Slave Granite rock is two billion years old, what were the circumstances that created these high temperatures and pressures to cause this type of rock to form? To answer this question, you have to first consider the composition of Earth's interior.



Earth's internal structure is not something you can observe directly because the deepest mines (4 km) and the deepest wells (13 km) barely scratch the surface—it's over 6000 km to the centre! The following description comes from indirect evidence that will be discussed in Chapter 2.

Earth can be separated into layers arranged according to their densities. The densest material sinks to the centre, while the least dense material floats on the surface. If you were to cut Earth in half, it might resemble a hard-boiled egg. You can think of the **core** as the yolk. The core is the densest layer and is made of nickel and iron.

- core: the innermost layer of Earth that consists of a solid inner core and a liquid outer core

The egg analogy isn't perfect, however. Unlike an egg yolk, Earth's core has two parts: a solid inner core and a liquid outer core. The liquid outer core spins compared with the rest of the planet. This induces Earth's magnetic field.

The white of the egg is like the **mantle**. The mantle is a solid layer comprising about 80% of Earth's volume. The extreme heat and pressure within the mantle cause zones of the rock to behave as a **plastic**. Every time you squeeze toothpaste out of a tube, for example, you are causing the flow of a plastic material. Earth's crust floats on the upper part of the mantle called the **asthenosphere**. The asthenosphere is the least rigid and most plastic part of the mantle. This plastic nature can be witnessed when magma from the asthenosphere rises up in the form of volcanoes.

- mantle: the layer of Earth between the crust and the core
- plastic: a substance with the properties of a solid that can flow under pressure
- asthenosphere: the uppermost layer of the mantle

- mesosphere: the part of the mantle beneath the asthenosphere
- lithosphere: Earth's outermost rigid layer of rock

The rest of the mantle beneath the asthenosphere is more rigid and is called the **mesosphere**. Do not confuse this with the part of the atmosphere that has the same name. The **lithosphere** is like the shell of the egg. The lithosphere includes the solid oceanic crust and continental crust that float on the asthenosphere. Oceanic crust is denser than continental crust and, as a result, is less buoyant.

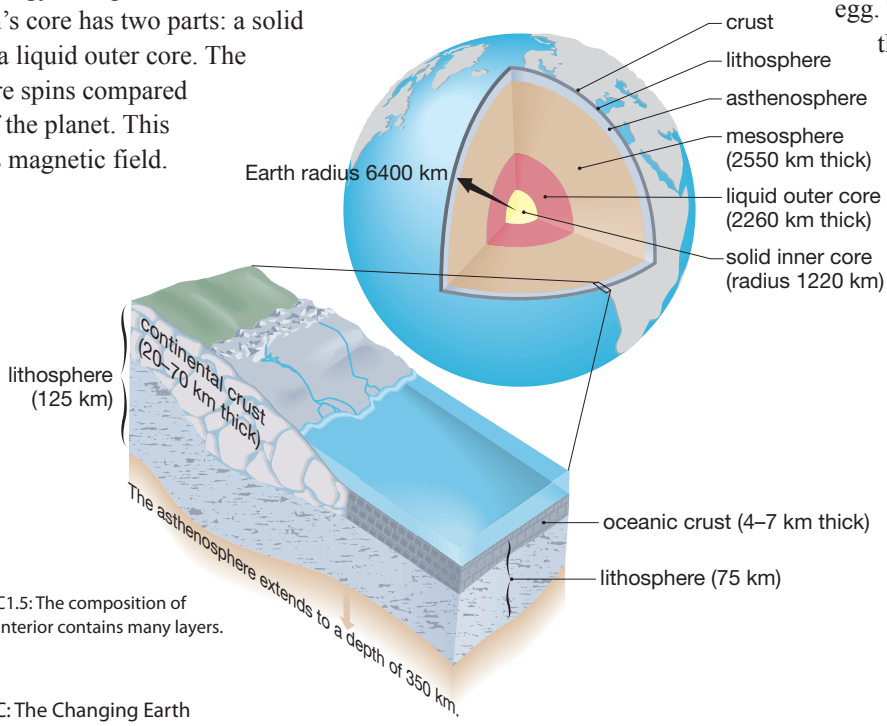


Figure C1.5: The composition of Earth's interior contains many layers.

Practice

1. Earth's internal structure can be compared to an egg. Infer what else Earth's internal structure can be compared to. Think of your own analogy. You could even make a poster or build a 3-D model to teach other people about Earth's interior.

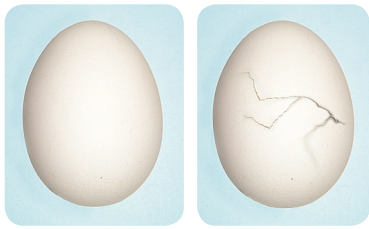
2. Copy and complete the table by inserting the missing information.

Earth's Layers		Density	Description	Thickness
atmosphere		least dense	• gaseous	300 km
			• solid • most rigid layer	
mantle			• least rigid or most plastic layer of mantle	
			• more rigid than uppermost layer of mantle	
core	outer core			
	inner core	most dense		

Motion in the Mantle

Scientists are unable to directly observe the layers below the lithosphere, so they use indirect evidence from events, such as earthquakes, to assist in developing theories about Earth's structure. One such theory is the idea that it is nuclear decay deep within the core that provides much of the heat energy needed to drive the plastic flow of material in the mantle. If this explanation is correct, the movement of matter in the mantle is similar to a hot bowl of French onion soup. Hotter material in the soup rises toward the cheesy crust; then it cools and sinks. This process, called convection, pushes and pulls on the soup's crust. This causes it to crack, tear, and move.

Scientists believe that a similar process is at work in Earth's mantle. Enormous convection cells within the mantle push and pull on Earth's solid crust. The results of convection require a revision to the idea that Earth is like an egg. The lithosphere is like the shell of an egg, but it is not a single rigid cover. Instead, the lithosphere is more like the cracked shell of the egg on the right—a mosaic of rigid pieces called **crustal plates**.



crustal plate: a large piece of continental crust or oceanic crust that floats and slowly moves atop the asthenosphere

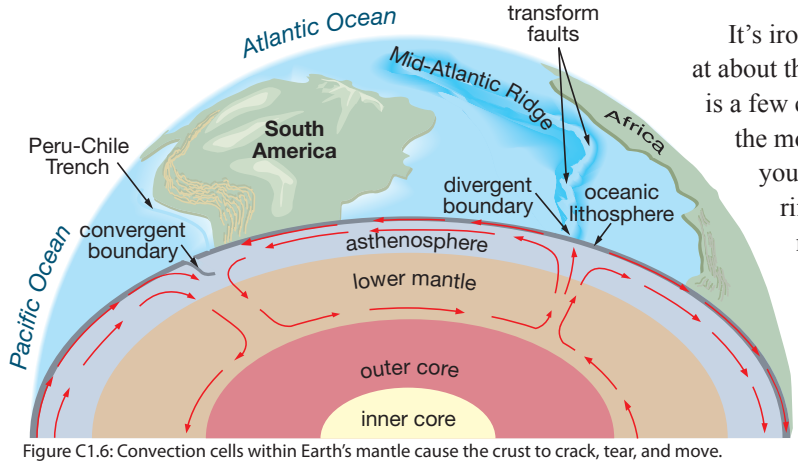


Figure C1.6: Convection cells within Earth's mantle cause the crust to crack, tear, and move.

It's ironic that these monstrous lithospheric plates move at about the same speed that your fingernails grow, which is a few centimetres per year. However, if you could watch the motion of Earth's crust in extreme fast forward, you would see a clumsy dance where crustal plates rift apart to create new oceans, collide to thrust up new mountain ranges, or slide one over the other to force one plate deep into the hot mantle to be melted. Since it isn't possible to see convection occurring within Earth's mantle, you can watch a demonstration of convection on the Science 20 Textbook CD.

Utilizing Technology

Convection

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting

Purpose

You will watch a demonstration of convection currents occurring within an aquarium. By the end of this activity you should be able to explain the process that causes convection currents to occur. The concepts that you explore here will be extended to explain the movement in Earth's crustal plates.

Procedure

step 1: Read the "Analysis" questions to create a focus for your learning before watching an applet.

step 2: Watch the applet "How Convection Works" on the Science 20 Textbook CD. Then complete the "Analysis" questions.

Analysis

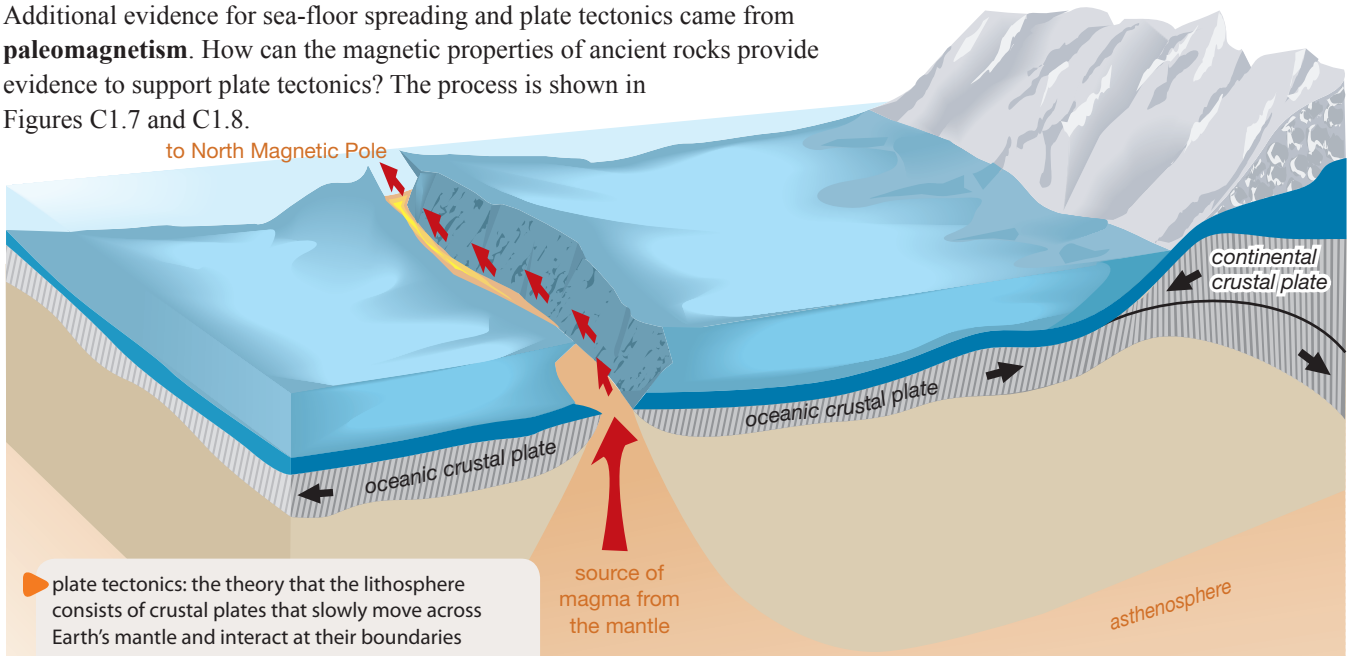
1. Identify the energy source in the demonstration.
2. Identify the energy source for Earth's convection.
3. Sketch a diagram of the demonstration. Beside it, draw a diagram of Earth's convection currents.
4. Summarize the applet's explanation of how convection works.
5. Describe the movement of fluid near the aquarium's surface. How would it affect something floating on the surface?

Dynamic Crust

The same principles that were demonstrated in the applet "How Convection Works" explain how the crustal plates are driven by convection currents of hot material from within the mantle. This explanation is called **plate tectonics**. When the crustal plates separate at mid-oceanic ridges, the process is called sea-floor spreading. This means the youngest rocks on oceanic plates are located closest to the spreading centre; the rocks steadily get older as they move away from the ocean ridges. This has been verified by deep-sea drilling operations. Core samples taken from the ocean floor show a steady increase in age away from the ocean ridges.

Paleomagnetism

Additional evidence for sea-floor spreading and plate tectonics came from **paleomagnetism**. How can the magnetic properties of ancient rocks provide evidence to support plate tectonics? The process is shown in Figures C1.7 and C1.8.



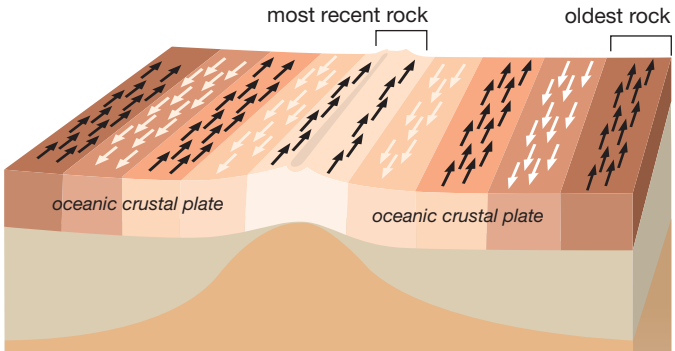
- plate tectonics: the theory that the lithosphere consists of crustal plates that slowly move across Earth's mantle and interact at their boundaries
- paleomagnetism: the study of the magnetic properties of rock formed in a past geological era

Figure C1.7: Plate tectonics is the process in which crustal plates are driven by convection currents or hot material from within the mantle.

Researchers found that sections of the sea floor have rocks with their magnetic fields pointing in the opposite direction, indicating that the magnetic field of Earth has reversed more than once in the past several million years. Refer to Figure C1.8.

The alternating normal and reversed stripes are parallel to the oceanic ridges. Researchers also discovered that the pattern of normal and reversed magnetic alignments on one side of an ocean ridge is the mirror image of the pattern on the other side. Researchers suggested that as new rock is added to each edge of the spreading plates, it records the current orientation of Earth's magnetic field. Paleomagnetism was one of the strongest pieces of evidence for sea-floor spreading and plate tectonics.

If two oceanic plates are slowly moving apart, a good question to ask is what happens at the end of each oceanic crustal plate that is opposite the fracture? As Figure C1.7 indicates, the edge of the oceanic crustal plate that is opposite the fracture is pushed under the neighbouring continental crustal plate. The oceanic crustal plate melts as it is forced down into the mantle. (You will take a closer look at this process when you study the formation of the Rocky Mountains in Chapter 2.)



step 1: When minerals rich in iron melt, they lose all their magnetic properties.

step 2: When magma cools and begins to solidify, any mineral rich in iron will have its magnetic particles align with Earth's magnetic field. The arrows on the diagram indicate that these magnetic particles are all pointing toward the North Magnetic Pole.

step 3: Rock formed from this magma then preserves a permanent record of the direction of Earth's magnetic field at the time of its solidification.

step 4: If you can use other means to determine the rock's age, you can determine the position of Earth's north and south magnetic poles at the time the magma solidified.

Figure C1.8: Rocks with magnetic fields pointing in opposite directions are found in sections of the sea floor.

Practice

3. Why is the oceanic crust pushed under the continental crustal plate instead of vice versa?

The Slave Granite

Recall the story of the Slave Granite that opened this lesson and the mystery about how the multicoloured crystals in the granite could have been formed under intense heat and pressure. Geologists now think that this rock was formed at the collision site of two continental crustal plates about two billion years ago. Since these plates had equal densities, one plate couldn't slide under the other. In this case, both plates welded together, pushing up huge rock wrinkles to form mountain ranges. At the site of the weld, the granite was formed and then pushed up. The mountain ranges that once stood tall have long since eroded. However, the Slave Granite remains as some of the oldest rock in Alberta.

1.1 Summary

Alberta's oldest rocks are two billion years old. But they are only about half as old as Earth, which was born 4.5 billion years ago. Earth survived violent interplanetary collisions and eventually settled into distinct layers—the core, the mantle, and the crust, depending on their density. Nuclear reactions continue to heat the core and mantle to cause enormous convection currents, which push and pull the plates that make up the crust.

1.1 Questions

Knowledge

1. Identify the first major section of time in Earth's history. Describe when it began and when it ended.
2. Where can you find Alberta's oldest exposed rocks?
3. Define *outcrop*.
4. Define *deep time*.
5. Sketch a simple, labelled diagram showing a cross section of Earth.
6. Infer the main property that determines both the ordering and composition of layers within Earth.

Applying Concepts

7. Like its name suggests, a lava lamp is a good model of Earth's convection currents. The semi-fluid material inside the lamp could represent the mantle. The heat source at the lamp's base could represent heat from Earth's core. A bubble starts at the bottom of the lamp, slowly rises, and then sinks again. Explain, step by step, the forces that affect the movement of fluid bubbles in the lava lamp.